Adult Women's Blood Mercury Concentrations Vary Regionally in USA: Association with Patterns of Fish Consumption (NHANES 1999-2004)

(Supplemental Material)

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Supplemental Material

U.S. EPA's Reference Dose for Methylmercury and Associated Blood Mercury Concentrations

A reference dose (RfD) is defined as "an estimate of daily exposure to the human population (including sensitive subgroups) that is likely to be without appreciable risk of deleterious effects during a lifetime" (Rice, 2004). The current RfD for methylmercury was developed in 2000 [see U.S. EPA's Water Quality Criteria (U.S. EPA 2008)]. These doses drew upon recommendations from the National Academy of Science/National Research Council's Committee of Toxicology of Methylmercury (NAS/NRC 2000). The dose-estimate was developed using benchmark dose methodology (Rice et al. 2003; Rice 2004; U.S. EPA June 2008; U.S. EPA Jan 2008). The U.S. EPA-derived Benchmark Dose Lower Limit (BMDL) was based on endpoints estimating child development in three epidemiological studies that assessed the association between in utero exposure to methylmercury and developmental outcomes: the Faroe Islands (Grandjean et al. 1997), the Seychelles Islands (Davidson et al. 1995 and 1998; Myers et al. 1995 and 1997), and New Zealand (Kjellstrom et al. 1986 and 1989). The RfD for methylmercury is 0.1 µg/kgbw /day and the BMDL is 1.0 µg/kgbw /day.

The BMDL of 1.0 µg/kgbw /day was associated with a cord BHg concentration of 58 µg/L. An Uncertainty Factor (UF) of 10 was applied to the BMDL to derive the RfD of 0.1 µg/kg bw /day. This overall UF included a factor of 3 for variability in the maternal elimination half-life and a factor of 3 for pharmacodynamic variability (Rice 2004; Rice et al. 2003). In this calculation, U.S. EPA, as well as the NAS/NRC Committee on the Toxicology of Methylmercury (NAS/NRC 2000) assumed a one:one

ratio of fetal cord BHg concentration compared to maternal BHg concentration. Subsequently Stern and Smith (2003) performed a Monte Carlo analysis of 10 published studies that estimated the ratio of cord blood to maternal blood as 1.6 to 1.8, with the 95th percentile being over 3.0. Additional post-2003 epidemiological observations support this finding (Sakamoto et al. 2004; Morrissette et al. 2004; Butler Walker et al. 2006).

Applying the UF of 10 to the BHg concentration associated with the BMDL (i.e., 58 µg Hg/L of whole cord blood) results in a cord whole BHg concentration of 5.8 µg Hg/L associated with exposures at the RfD. Because of the subsequent (i.e., post-2000) recognition of placental concentration of methylmercury (meaning that maternal BHg concentrations are lower than cord BHg concentrations), a BHg concentration in the range of ~ 3.5 µg/L whole maternal blood was considered to be associated with methylmercury exposures at the RfD. This is well reflected in Table 2 of the IRIS document (U.S. EPA Jan 2008) which indicates that the BMDL and the corresponding RfD calculated are based on a one-compartment model. The formula for the one-compartment model for converting exposure of the fetus based on daily methylmercury ingested by the mother does not include a factor for cord blood to maternal blood differences. The text of the IRIS web site states: “EPA has chosen not to make a numerical adjustment between cord-blood and maternal-BHg. At this time the relationship between cord-blood and maternal-BHg is considered subject to variability and uncertainty, and is to be included in the determination of the uncertainty factor (UF).” Unfortunately the text (U.S. EPA Jan 2008) is not clear that this is to be done in the future. The text of the IRIS web site (U.S. EPA Jan 2008)) states: “The two major phenomena included in the intraspecies UF for methylmercury were interindividual

toxicokinetic variability in ingested dose estimation and pharmacodynamic variability and uncertainty. For the former, EPA relied in part on the NRC analyses of variability in the pharmacokinetic factors underlying the conversion of a biomarker level of methylmercury to an ingested daily dose of methylmercury that corresponds to that level. EPA chose not to make a numerical adjustment in the dose conversion for the potential differences between cord- and maternal-BHg levels, but rather to consider them additional aspects of toxicokinetic variability and uncertainty."

The UF of 10 reflects the pre-2000 understanding of variability and uncertainty associated with methylmercury exposure and toxicity. There are multiple views of the size of this UF including the recommendation that methylmercury should be treated like inorganic lead with no level considered without adverse effects (U.S. EPA Jan 2008). The 2000 BMDL for methylmercury is an effect level in which there is a doubling of the likelihood that a child's scores of various tests of neurobehavioral function fall into the clinically subnormal range. Nonetheless, early reports (i.e., nearer 2000) of the NHANES BHg data for adult women (Schober et al. 2003) utilized 5.8 µg/L as the woman's BHg concentration reflecting the cord BHg associated with the RfD. Subsequent recognition of the placental concentration of methylmercury suggested that a lower mercury concentration is more appropriate when describing women's BHg concentrations associated with the RfD.

Additional risk assessments and guidelines exist for methylmercury exposures (summarized by Mergler et al. 2007). The NAS/NRC of U.S. (2000), the U.S. EPA (Jan 2008), and JECFA (2003) utilized a benchmark dose approach to establish risk levels.

However, these assessments differ in their choice of study/studies on which to base the assessment, the biomarker of exposure, and the magnitude of the UF. The NAS/NRC (2000), U.S. EPA (2001), Canada (Health Canada 2007), and the European Union (EU 2002) based their analyses on cord blood, whereas, the JECFA utilized maternal hair.

The JECFA committee considered that a maternal hair mercury concentration of > 14 ppm was associated with neurotoxicity associated with in utero exposure to methylmercury (pg 20, JECFA 2003). Then JECFA using a hair: blood ratio of 250 calculated maternal BHg of 56 µg/L to be without appreciable adverse effect. The JECFA Provisional Weekly Tolerable Intake (PTWI) would be associated with an associated with a BHg concentration of ~ 8.6 µg/L among adult women. The committee calculated a total UF of 6.4 to derive a PTWI of 1.6 µg/kgbw which if calculated on a daily basis becomes 0.23 µg/kgbw/day. The Joint FAO/WHO Expert Committee on Food Additives (2003) assessment, like the NAS/NRC (2000) and the U.S. EPA (2001) assessments did not specifically consider bioconcentration of methylmercury by the placenta and no changes in methylmercury excretion related to recently identified differences in genetic variability.

A major aspect of uncertainty is that all of the metabolic and kinetic differences cannot be anticipated that will be subsequently identified as important. Examples of this can be seen in the reports of genetic differences among humans in mercury excretion that were published after 2000 (Custodio et al. 2004; Engström et al. 2008). Consequently both of the BHg concentrations, 3.5µg/L and 5.8 µg/L have been utilized in the current manuscript as BHg concentrations of interest. As more is learned about factors that

influence distribution of methylmercury from mother to fetus and/or effects of methylmercury, the BMDL and the associated BHg concentations may change.

With regard to the BMDL, because no UFs were applied, a cord BHg of 58 µg/L will be predicted by a maternal BHg of ~ 35 µg/L. Subsequent epidemiological findings on additional factors affecting this ratio could alter the maternal BHg associated with the BMDL of 1.0 µg/kg bw /day.

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Supplemental Material, Table 1. Decision Factors Utilized in Risk Assessment for Methylmercury

Decision Factors Utilized in Risk Assessments for Methylmercury					
	U.S. NAS/NRC, 2000	U.S. EPA 2001	JECFA 2003	EU, 2002	U.S. ATSDR 1999
Studies	Utilized Faroes, New Zealand, Seychelles. Final value based on Faroes.	Utilized Faroes, New Zealand, Seychelles. Final value based on all three studies.	Utilized Faroes, New Zealand, Seychelles. Final value based on Faroes and Seychelles	Utilized Faroe Islands and Seychelles. Final value based on Faroe Islands	Utilized Seychelles study (Davidson et al., 1998)
Biomarker used as index for BMDL, Uncertainty Factor (UF) utilized.	Cord blood. µg/L. 58 µg/L in cord blood. UF ~ 10. 3.2 for toxicokinetics, 3.2 for toxicodynamics.	Cord blood. µg/L. 58 µg/L in cord blood. UF ~ 10. 3.2 for toxicokinetics, 3.2 for toxicodynamics	Maternal Hair. µg/gm or ppm. 14 ppm maternal hair. 3.2 for individual variation x 2 for overall average interindividual variation. Total UF ~ 6.4. No toxicodynamic factor.	Cord blood µg/L. 58 µg/L in cord blood. UF ~ 10. 3.2 for toxicokinetics, 3.2 for toxicodynamics.	Maternal hair, 15.3 ppm. UF 4.5
Limits of Exposure	Reference Dose, 0.1 µg/kgbw/day	Reference Dose, 0.1 µg/kgbw/day	Provisional Weekly Tolerable Intake 1.6 µg/kgbw/week (equal to 0.23 µg/kgbw/day).	No Observed Adverse Effect Level (NOAEL) 0.1 µg/kgbw/day	Minimum Risk Level (MRL) 0.3 µg/kgbw/day

Supplemental Material, Table 2. Blood total mercury (µg/L), women 16-49 years, by Census Region. NHANES 1999-2004.

	N	Geo. Mean	95% CI		Arith. Mean	95% CI		Percentiles						
								5th	10th	25th	50th	75th	90th	95th
Total	5,365	0.89	0.82	0.96	1.59	1.41	1.76	0.1	0.2	0.4	0.9	1.7	3.6	5.4
Census Region														
Midwest	937	0.66	0.58	0.74	0.99	0.87	1.11	0.1	0.2	0.4	0.7	1.2	2.1	2.7
Northeast	820	1.14	0.84	1.56	2.21	1.52	2.91	0.1	0.2	0.6	1.1	2.6	5.2	8.2
South	2,114	0.90	0.80	1.02	1.64	1.40	1.87	0.1	0.2	0.5	0.9	1.7	3.7	5.5
West	1,494	0.95	0.82	1.09	1.61	1.39	1.83	0.1	0.2	0.5	1.0	1.9	3.6	5.7

Supplemental Material, Table 3. Estimated 30-day mercury intake (µg Hg/kg_{bw}), women 16-49 years, by Census Region. NHANES 1999-2004.

	N	Arith. Mean	95% CI		Percentiles						
					5th	10th	25th	50th	75th	90th	95th
Total	5,315	0.67	0.62	0.73	0.00	0.00	0.07	0.36	0.81	1.57	2.31
Census Region											
Midwest	937	0.48	0.43	0.52	0.00	0.00	0.05	0.31	0.66	1.15	1.53
Northeast	822	0.87	0.67	1.07	0.00	0.00	0.04	0.45	1.14	2.23	3.38
South	2,105	0.69	0.61	0.78	0.00	0.00	0.08	0.37	0.81	1.67	2.38
West	1,451	0.68	0.57	0.79	0.00	0.00	0.08	0.36	0.80	1.47	2.26

Supplemental Material, Table 4. Blood total mercury (µg/L), women 16-49 years, by inland region and coast. NHANES 1999-2004.

	N	Geo. Mean	95% CI		Arith. Mean	95% CI		Percentiles						
								5th	10th	25th	50th	75th	90th	95th
Total	5,365	0.89	0.82	0.96	1.59	1.41	1.76	0.14	0.20	0.40	0.90	1.70	3.60	5.40
Region/Coast														
Atlantic	885	1.55	1.32	1.81	2.83	2.42	3.24	0.20	0.40	0.70	1.60	3.40	7.00	10.9
Pacific	974	1.18	1.04	1.35	1.98	1.72	2.23	0.14	0.30	0.60	1.20	2.40	4.50	6.80
Gulf	354	0.96	0.80	1.16	1.62	1.26	1.98	0.20	0.30	0.50	0.90	1.80	3.70	5.20
Great Lakes	390	0.80	0.68	0.94	1.07	0.91	1.23	0.20	0.30	0.50	0.90	1.40	2.00	2.60
Northeast	289	0.77	0.55	1.06	1.44	0.86	2.03	0.10	0.14	0.40	0.80	1.70	3.50	4.80
South	1,352	0.74	0.64	0.87	1.26	0.93	1.59	0.10	0.20	0.40	0.80	1.30	2.70	4.00
West	520	0.73	0.60	0.87	1.17	0.95	1.40	0.10	0.20	0.40	0.80	1.40	2.50	3.30
Midwest	601	0.63	0.56	0.70	0.98	0.84	1.13	0.10	0.20	0.30	0.70	1.20	2.20	3.00
Coastal Status														
Coastal	2,603	1.19	1.07	1.34	2.11	1.82	2.40	0.20	0.30	0.60	1.20	2.40	4.90	7.20
Non-coastal	2,762	0.71	0.64	0.78	1.19	1.02	1.37	0.10	0.20	0.40	0.70	1.30	2.50	3.80

Supplemental Material, Table 5. Estimated 30-day mercury intake (µg Hg/kg_{bw}), women 16-49 years, by inland region and coast. NHANES 1999-2004.

		Arith.				Percentiles						
		Mean	SE	95% CI		5th	10th	25th	50th	75th	90th	95th
Total	5,315	0.67	0.03	0.62	0.73	0.00	0.00	0.07	0.36	0.81	1.57	2.31
Region												
Great Lakes	399	0.47	0.04	0.39	0.54	0.00	0.00	0.05	0.30	0.66	1.15	1.37
Midwest	593	0.50	0.03	0.44	0.55	0.00	0.00	0.05	0.32	0.67	1.20	1.56
West	515	0.59	0.05	0.49	0.68	0.00	0.00	0.11	0.37	0.80	1.35	1.99
South	1,365	0.62	0.06	0.50	0.74	0.00	0.00	0.07	0.34	0.75	1.24	2.03
Northeast	287	0.65	0.07	0.50	0.79	0.00	0.00	0.00	0.33	0.91	1.66	2.29
Gulf	333	0.69	0.05	0.59	0.79	0.00	0.00	0.08	0.38	0.87	1.82	2.63
Pacific	936	0.76	0.11	0.54	0.98	0.00	0.00	0.07	0.34	0.78	1.83	2.59
Atlantic	887	1.00	0.07	0.86	1.13	0.00	0.00	0.09	0.52	1.28	2.44	3.88
Coastal Status												
Coastal	2,555	0.79	0.05	0.69	0.90	0.00	0.00	0.08	0.40	0.93	1.94	3.13
Non-coastal	2,760	0.59	0.03	0.53	0.64	0.00	0.00	0.06	0.35	0.75	1.30	1.98

Supplemental Material, Table 6. Blood total mercury (µg/L), women 16-49 years, by race/ethnicity and annual income. NHANES 1999-2004.

	N	Geo. Mean	95% CI		Arith. Mean	SE	95% CI		Percentiles 5th	10th	25th	50th	75th	90th	95th
Total U.S. W 16-49 yrs	5,365	0.89	0.82	0.96	1.59	0.09	1.41	1.76	0.14	0.2	0.4	0.9	1.7	3.6	5.4
Race/Ethnicity															
Mexican American	1,512	0.70	0.62	0.78	1.11	0.05	1.00	1.21	ND	0.2	0.4	0.7	1.3	2.2	3.3
Other Hispanic	285	0.97	0.77	1.23	1.78	0.32	1.14	2.42	ND	0.2	0.5	1.0	2.0	3.4	4.8
Non-Hispanic White	2,110	0.83	0.75	0.92	1.50	0.11	1.28	1.72	ND	0.2	0.4	0.8	1.6	3.4	5.4
Non-Hispanic Black	1,252	1.13	1.00	1.26	1.78	0.13	1.50	2.05	0.2	0.4	0.6	1.1	2.0	3.5	5.2
Other Race	206	1.45	1.16	1.81	2.79	0.29	2.21	3.37	0.2	0.4	0.6	1.5	3.8	6.5	8.9
Annual Income															
$0-9,999	430	0.69	0.58	0.82	1.13	0.14	0.85	1.41	ND	0.2	0.4	0.7	1.3	2.6	3.2
$10,000-19,999	774	0.72	0.63	0.83	1.26	0.16	0.94	1.57	0.14	0.2	0.4	0.7	1.3	2.5	3.6
$20,000-34,999	1,020	0.80	0.71	0.91	1.41	0.12	1.17	1.65	ND	0.2	0.4	0.8	1.6	2.8	4.1
$35,000-54,999	916	0.86	0.75	0.98	1.54	0.13	1.27	1.80	0.14	0.2	0.5	0.8	1.7	3.3	5.9
$55,000-74,999	595	0.91	0.78	1.06	1.63	0.15	1.33	1.94	0.14	0.2	0.4	0.9	1.7	3.8	6.2
$75,000+	1,028	1.12	1.00	1.26	1.94	0.15	1.65	2.24	0.14	0.3	0.6	1.1	2.3	4.7	6.8

Supplemental Material, Table 7. Reported frequency of consumption of fish/shellfish in 30-days, women 16-49 years, by race/ethnicity and annual income. NHANES 1999-2004.

	N	Arith. Mean	SE	95%CI		Percentiles 5th	10th	25th	50th	75th	90th	95th
Total	5,388	4.57	0.2	4.25	4.88	0.0	0.0	1.0	3.0	6.0	11.0	15.0
Race/Ethnicity												
Mexican American	1,495	2.88	0.1	2.61	3.15	0.0	0.0	1.0	2.0	4.0	7.0	9.0
Other Hispanic	287	4.06	0.5	3.10	5.02	0.0	0.0	1.0	2.0	5.0	10.0	13.0
Non-Hispanic White	2,129	4.43	0.2	4.04	4.83	0.0	0.0	1.0	3.0	6.0	11.0	14.0
Non-Hispanic Black	1,263	5.24	0.3	4.73	5.75	0.0	0.0	1.0	3.0	6.0	12.0	17.0
Other Race	214	8.17	1.4	5.40	11.0	0.0	0.0	1.0	4.0	10.0	18.0	25.0
Annual Income												
$0-9,999	426	3.65	0.5	2.61	4.70	0.0	0.0	0.0	2.0	4.0	11.0	16.0
$10,000-19,999	756	3.79	0.3	3.25	4.34	0.0	0.0	1.0	2.0	5.0	9.0	12.0
$20,000-34,999	1,025	4.13	0.3	3.59	4.66	0.0	0.0	1.0	2.0	5.0	10.0	15.0
$35,000-54,999	938	4.33	0.3	3.76	4.90	0.0	0.0	1.0	3.0	6.0	10.0	15.0
$55,000-74,999	598	5.33	0.5	4.25	6.41	0.0	0.0	1.0	3.0	7.0	12.0	15.0
$75,000+	1,032	5.23	0.2	4.74	5.71	0.0	0.0	1.0	3.0	7.0	12.0	15.0

Supplemental Material, Table 8. Estimated 30-day mercury intake (µg Hg/kg_{bw}), women 16-49 years, by race-ethnicity and annual income. NHANES 1999-2004.

	N	Arith. Mean	SE	95% CI		Percentiles 5th	10th	25th	50th	75th	90th	95th
Total	5,315	0.67	0.03	0.62	0.73	0.00	0.00	0.07	0.36	0.81	1.57	2.31
Race/Ethnicity												
Mexican American	1,485	0.42	0.02	0.38	0.47	0.00	0.00	0.02	0.22	0.55	0.98	1.41
Other Hispanic	283	0.59	0.07	0.45	0.74	0.00	0.00	0.04	0.25	0.74	1.70	2.40
Non-Hispanic White	2,101	0.68	0.04	0.60	0.76	0.00	0.00	0.06	0.38	0.82	1.59	2.39
Non-Hispanic Black	1,239	0.65	0.03	0.59	0.71	0.00	0.00	0.14	0.40	0.84	1.49	2.17
Other Race	207	1.21	0.26	0.69	1.73	0.00	0.00	0.14	0.60	1.28	2.24	4.67
Annual Income												
$0-9,999	420	0.58	0.12	0.34	0.82	0.00	0.00	0.00	0.23	0.61	1.39	2.41
$10,000-19,999	746	0.53	0.04	0.46	0.61	0.00	0.00	0.09	0.33	0.70	1.32	1.86
$20,000-34,999	1,008	0.61	0.04	0.52	0.70	0.00	0.00	0.05	0.34	0.75	1.24	2.32
$35,000-54,999	918	0.66	0.05	0.55	0.77	0.00	0.00	0.06	0.34	0.76	1.66	2.63
$55,000-74,999	595	0.75	0.10	0.54	0.95	0.00	0.00	0.10	0.44	0.90	1.57	2.38
$75,000+	1,024	0.78	0.05	0.67	0.88	0.00	0.00	0.12	0.43	0.93	1.79	2.41

Supplemental Material, Table 9. Blood total mercury (µg/L), estimated fish/shellfish consumed in 30-days (g), estimated intake of mercury in 30-days (µg Hg), and estimated intake of mercury normed to body weight in 30-days (µg Hg/kg bw), women 16-49 years, by NHANES study years. NHANES 1999-2004.

		Geo			Percentiles						
	N	Mean	95% CI		5th	10th	25th	50th	75th	90th	95th
Blood Total Mercury (µg/L)											
1999-2000	1,709	1.02	0.82	1.27	0.10	0.20	0.50	1.00	2.10	4.90	7.20
2001-2002	1,928	0.83	0.74	0.94	0.10	0.20	0.40	0.80	1.70	3.10	4.60
2003-2004	1,728	0.83	0.72	0.94	0.14	0.20	0.40	0.80	1.60	3.10	4.40
		Arith			Percentiles						
	N	Mean	95% CI		5th	10th	25th	50th	75th	90th	95th
Est. g fish consumed in 30-days											
1999-2000	1,732	310	265	355	0.0	0.0	45.2	180	403	750	1,114
2001-2002	1,934	346	314	377	0.0	0.0	69.3	203	424	777	1,115
2003-2004	1,722	307	269	344	0.0	0.0	52.5	196	448	756	974
Est. intake of µg Hg											
1999-2000	1,732	48.9	40.0	57.8	0.0	0.0	2.86	22.8	56.0	121	202
2001-2002	1,934	50.2	43.5	56.9	0.0	0.0	10.1	27.6	59.2	108	166
2003-2004	1,722	40.7	35.6	45.8	0.0	0.0	3.14	25.6	56.6	105	135
Est. intake of µg Hg / kg bw											
1999-2000	1,724	0.71	0.56	0.86	0.00	0.00	0.05	0.33	0.77	1.72	2.86
2001-2002	1,889	0.72	0.62	0.82	0.00	0.00	0.12	0.40	0.86	1.57	2.35
2003-2004	1,702	0.58	0.50	0.66	0.00	0.00	0.04	0.35	0.81	1.40	2.01

Supplemental Material, Table 10. Percent of women 16-49 years old with blood total mercury values over thresholds, by study year. NHANES 1999-2004.

	<3.5 ug/L		3.5-<5.8 ug/L		>=5.8 ug/L	
	%	SE	%	SE	%	SE
1999-2000	85.6	2.7	7.5	1.4	6.9	1.6
2001-2002	92.3	0.9	4.1	0.6	3.7	0.8
2003-2004	92.5	1.1	5	0.9	2.4	0.8

Supplemental Material, Table 11. Multiple regression results for dependent variable Blood Total Mercury (µg/L), log scale. Estimated regression coefficients.

	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	-0.985	0.065	-15.26	<.0001
Race/Ethnicity				
Other Race	0.314	0.094	3.34	0.0017
Non-Hispanic Black	0.224	0.042	5.3	<.0001
Other Hispanic	0.136	0.088	1.53	0.1325
Non-Hispanic White	0.000	0.000	.	.
Mexican American	-0.040	0.049	-0.82	0.4191
Age	0.019	0.001	17.52	<.0001
Est. 30-day mercury intake (µg Hg/kg_{bw})	0.327	0.038	8.54	<.0001
Data Release				
1999-2000	0.421	0.040	10.58	<.0001
2003-2004	0.000	0.000	.	.
2001-2002	-0.267	0.093	-2.89	0.006
Inland Region/Coastal Area				
Atlantic	0.351	0.089	3.95	0.0003
Pacific	0.269	0.041	6.59	<.0001
Gulf	0.166	0.036	4.65	<.0001
West	0.000	0.000	.	.
Great Lakes	0.000	0.069	-0.01	0.9953
South	-0.213	0.115	-1.86	0.0697
Midwest	-0.377	0.073	-5.13	<.0001
Northeast	-0.472	0.042	-11.22	<.0001
Annual Income				
$75,000+	0.000	0.000	.	.
$55,000-74,999	-0.079	0.051	-1.55	0.1293
$35,000-54,999	-0.112	0.037	-3.05	0.0038
$20,000-34,999	-0.157	0.041	-3.79	0.0005
$0-9,999	-0.198	0.057	-3.5	0.0011
$10,000-19,999	-0.211	0.052	-4.06	0.0002
Interaction Inland Region/Coastal Area*Data Release (comparison 2003-2004 and West)				
Northeast 2001-2002	0.988	0.139	7.13	<.0001
South 2001-2002	0.461	0.143	3.22	0.0024
Atlantic 2001-2002	0.322	0.134	2.4	0.0206
Midwest 2001-2002	0.306	0.174	1.76	0.0849
Gulf of Mexico 2001-2002	0.134	0.111	1.21	0.2326
Pacific 2001-2002	0.114	0.112	1.02	0.3152
Pacific 1999-2000	-0.117	0.092	-1.26	0.2131
South 1999-2000	-0.197	0.134	-1.47	0.149
Midwest 1999-2000	-0.232	0.124	-1.87	0.0676
Atlantic 1999-2000	-0.250	0.105	-2.38	0.0217
Northeast 1999-2000	-0.279	0.079	-3.56	0.0009
Gulf of Mexico 1999-2000	-0.335	0.061	-5.51	<.0001
Great Lakes 1999-2000	-0.661	0.125	-5.3	<.0001

NOTE: N=4,507; R2=0.27

Supplemental Material, Table 12. Summary of mercury concentrations in fish species (µg Hg/g fresh weight).

Fish Species	Average (µg Hg/g)	Source
Sharks	1.327	U.S.EPA Mercury study (1997)
Swordfish	0.95	U.S.EPA Mercury study (1997)
Porgy	0.522	NMFS Report (1978)
Walleye	0.52	U.S.EPA (1992), Bahnick et al. (1994)
Tuna, fresh	0.41	U.S. FDA (2006)[c], Dabeka et al (2004)
Bass, Freshwater	0.38	U.S.EPA (1992), Bahnick et al. (1994)
Northern Pike	0.31	U.S.EPA (1992), Bahnick et al. (1994)
Halibut	0.25	U.S.EPA Mercury study (1997)
Snapper	0.25	U.S.EPA Mercury study (1997)
Lobster	0.232	U.S.EPA Mercury study (1997)
Tuna, not specified[a]	0.22	U.S. FDA (2006), Dabeka et al (2004)
Tuna, canned	0.20	U.S. FDA (2006), Dabeka et al (2004)
Skate	0.176	NMFS Report (1978)
Catfish, Channel and Flathead	0.16	U.S.EPA (1992), Bahnick et al. (1994)
Pollock	0.15	U.S.EPA Mercury study (1997)
Trout	0.149	U.S.EPA Mercury study (1997)
Brown Trout	0.14	U.S.EPA (1992), Bahnick et al. (1994)
Sea Bass	0.135	NMFS Report (1978)
Croaker	0.125	U.S.EPA Mercury study (1997)
Cod	0.121	U.S.EPA Mercury study (1997)
Crab	0.117	U.S.EPA Mercury study (1997)
Perch, Ocean	0.116	U.S.EPA Mercury study (1997)
Carp	0.11	U.S.EPA (1992), Bahnick et al. (1994)
Perch, White and Yellow	0.11	U.S.EPA Mercury study (1997)
Pompano	0.104	U.S.EPA Mercury study (1997)
Sardines	0.1	NMFS Report (1978)
Smelt	0.1	U.S.EPA Mercury study (1997)
Carp, Common	0.093	U.S.EPA Mercury study (1997)
Flounders	0.092	U.S.EPA Mercury study (1997)
Haddock	0.089	U.S.EPA Mercury study (1997)
Catfish (channel, large mouth, rock, striped, white)	0.088	U.S.EPA Mercury study (1997)
Mackerel (not King Mackerel)	0.081	U.S.EPA Mercury study (1997)
Crab, King	0.07	U.S.EPA Mercury study (1997)
Anchovy	0.047	U.S.EPA Mercury study (1997)
Shrimp	0.047	U.S.EPA Mercury study (1997)
Scallops	0.042	U.S.EPA Mercury study (1997)
Whiting (silver hake)	0.041	NMFS Report (1978)
Salmon	0.035	U.S.EPA Mercury study (1997)
Crayfish	0.033	U.S.FDA (2006)
Octopus.	0.029	U.S.EPA Mercury study (1997)
Squid	0.026	U.S.EPA Mercury study (1997)
Clams	0.023	U.S.EPA Mercury study (1997)
Oysters	0.023	U.S.EPA Mercury study (1997)
Abalone	0.016	U.S.EPA Mercury study (1997)
Herring	0.013	U.S.EPA Mercury study (1997)
Mullet	0.009	U.S.EPA Mercury study (1997)

[a] Tuna, not specified as to canned or fresh was given a concentration value weighted by market share.

FDA, 2006. Mercury Levels in Commercial Fish and Shellfish. http://www.cfsan.fda.gov/~frf/sea-mehg.html.Dabeka, R., McKenzie, A.D., Forsyth, D.S., Conacher, H.B.S. 2004. Survey of Total Mercury in Some Edible Fish and Shellfish Species Collected in Canada in 2002. Food Additives and Contaminants. 21(5):434-440.

Supplemental Material, Table 13. List of counties comprising coastal regions

Atlantic Ocean	Gulf of Mexico	Pacific Ocean	Great Lakes
Connecticut	Alabama	Alaska	Michigan
Fairfield County	Baldwin County	(Includes Arctic Ocean coast)	Keweenaw
Hartford County	Mobile County	Aleutians East Borough	Gogebic
Middlesex County		Aleutians West	Ontonagon
New Haven County	Florida	Anchorage Borough	Houghton
New London County	Alachua County	Bethel	Baraga
Tolland County	Bay County	Bristol Bay Borough	Marquette
Windham County	Calhoun County	City & Borough of Juneau	Alger
	Charlotte County	City & Borough of Sitka	Luce
Delaware	Citrus County	Dillingham	Chippewa
(Entire state)	Collier County	Haines Borough	Mackinac
Kent County	Columbia County	Kenai Peninsula Borough	Schoolcraft
New Castle County	DeSoto County	Ketchikan Gateway Borough	Delta
Sussex County	Dixie County	Kodiak Island Borough	Menominee
	Escambia County	Lake And Peninsula Borough	Berrien
District Of Columbia	Franklin County	Nome	Van Buren
District Of Columbia	Gadsden County	North Slope Borough	Allegan
	Gilchrist County	Northwest Arctic Borough	Ottawa
Florida	Glades County	Prince of Wales-Outer Ketchikan	Muskegon
Baker County	Gulf County	Skagway-Hoonah-Angoon	Oceana
Bradford County	Hamilton County	Valdez-Cordova	Mason
Brevard County	Hardee County	Wade Hampton	Manistee
Broward County	Hendry County	Wrangell-Petersburg	Benzie
Clay County	Hernando County	Yakutat	Leelanau
Duval County/ City of Jacksonville	Highlands County		Chrand Traverse
Flagler County	Hillsborough County	California	Antrim
Indian River County	Holmes County	Alameda County	Charlevoix
Lake County	Jackson County	Contra Costa County	Emmet
Martin County	Jefferson County	Del Norte County	Cheboygan
Miami-Dade County	Lafayette County	Humboldt County	Presque Isle
Nassau County	Lee County	Los Angeles County	Alpena
Okeechobee County	Leon County	Marin County	Alcona
Orange County	Levy County	Mendocino County	Iosco
Osceola County	Liberty County	Monterey County	Arenac
Palm Beach County	Madison County	Napa County	Bay
Putnam County	Manatee County	Orange County	Tuscola
Seminole County	Marion County	San Diego County	Huron
St. Johns County	Monroe County	San Francisco City & County	Sanilac
St. Lucie County	Okaloosa County	San Luis Obispo County	St. Clair
Union County	Pasco County	San Mateo County	Macomb
Volusia County	Pinellas County	Santa Barbara County	Wayne
	Polk County	Santa Clara County	Monroe
Georgia	Santa Rosa County	Santa Cruz County	Genesee
Bryan County	Sarasota County	Solano County	Lapeer
Camden County	Sumter County	Sonoma County	Oakland

Supplemental Material, Table 13. List of counties comprising coastal regions (continued)

Atlantic Ocean	Gulf of Mexico	Pacific Ocean	Great Lakes
Chatham County	Suwanee County	Ventura County	Washtenaw
Glynn County	Taylor County		Saginaw
Liberty County	Wakulla County	**Hawaii**	Kalkaska
McIntosh County	Walton County	**(Entire state)**	Midland
	Washington County	Hawaii County	Gladwin
Maine		Honolulu City and County	
Androscoggin County	**Louisiana**	Kalawao	**Wisconsin**
Cumberland County	Assumption Parish	Kauai County	Douglas
Hancock County	Cameron Parish	Maui County	Bayfield
Kennebec County	Iberia Parish	Midway Islands	Ashland
Knox County	Jefferson Parish		Iron
Lincoln County	Lafayette Consolidated Government	**Oregon**	Marinette
Sagadahoc County	Lafourche Parish	Clatsop County	Oconto
Waldo County	Livingston Parish	Columbia County	Door
Washington County	Orleans Parish	Coos County	Brown
York County	Plaquemines Parish	Curry County	Kewaunee
	St. Bernard Parish	Douglas County	Manitowoc
Maryland	St. Charles Parish	Lane County	Sheboygan
Anne Arundel County	St. James Parish	Lincoln County	Ozaukee
Baltimore City	St. John The Baptist Parish	Multnomah County	Milwaukee
Baltimore County	St. Mary Parish	Tillamook County	Racine
Calvert County	St. Tammany Parish	Washington County	Kenosha
Caroline County	Tangipahoa Parish		Waukesha
Cecil County	Terrebonne Parish	**Washington**	Washington
Charles County	Vermilion Parish	Clallam County	Calumet
Dorchester County		Clark County	
Harford County	**Mississippi**	Cowlitz County	**Ohio**
Howard County	Hancock County	Grays Harbor County	Lucas
Kent County	Harrison County	Island County	Ottawa
Montgomery County	Jackson County	Jefferson County	Erie
Prince George's County		King County	Lorain
Queen Anne's County	**Texas**	Kitsap County	Cuyahoga
Somerset County	Aransas County	Mason County	Lake
St. Mary's County	Brazoria County	Pacific County	Ashtabula
Talbot County	Calhoun County	Pierce County	Geauga
Wicomico County	Cameron County	San Juan County	Summit
Worcester County	Chambers County	Skagit County	Medina
	Galveston County	Snohomish County	Sandusky
Massachusetts	Harris County	Thurston County	Wood
Barnstable County	Jackson County	Wahkiakum County	Huron
Bristol County	Jefferson County	Whatcom County	Seneca
Dukes County	Kenedy County		
Essex County	Kleberg County		**New York**
Middlesex County	Matagorda County		Chautauqua
Nantucket County	Nueces County		Erie

Supplemental Material, Table 13. List of counties comprising coastal regions (continued)

Atlantic Ocean	Gulf of Mexico	Great Lakes
Norfolk County	Orange County	Niagara
Plymouth County	Refugio County	Orleans
Suffolk County	San Patricio County	Monroe
	Victoria County	Wayne
New Hampshire	Willacy County	Cayuga
Rockingham County		Oswego
Strafford County		Jefferson
		Livingston
New Jersey		Genesee
Atlantic County		Ontario
Bergen County		Seneca
Burlington County		Onondaga
Camden County		Cattaraugus
Cape May County		Wyoming
Cumberland County		
Essex County		**Minnesota**
Glouchester County		Cook
Hudson County		Lake
Middlesex County		St. Louis
Monmouth County		Carlton
Ocean County		
Passaic County		**Indiana**
Salem County		Lake
Union County		Porter
		LaPorte
New York		
Bronx County		**Illinois**
Kings County (Brooklyn)		Lake
Nassau County		Cook
New York City (all 5 boroughs)		DuPage
New York County (Manhattan)		McHenry
Queens County		Kane
Richmond County (Staten Island)		Will
Rockland County		
Suffolk County		**Pennsylvania**
Westchester County		Erie
		Crawford
North Carolina		
Beaufort County		
Bertie County		
Brunswick County		
Camden County		
Carteret County		
Chowan County		
Craven County		
Currituck County		

Supplemental Material, Table 13. List of counties comprising coastal regions (continued)

Atlantic Ocean	Atlantic Ocean(continued)
Dare County	**Virginia (continued)**
Hyde County	Henrico County
Jones County	Isle of Wight County
New Hanover County	James City County
Onslow County	King and Queen County
Pamlico County	King George County
Pasquotank County	Lancaster County
Pender County	Manassas City
Perquimans County	Manassas Park City
Tyrrell County	Matthews County
Washington County	Middlesex County
	New Kent County
Pennsylvania	Newport News City
Delaware County	Norfolk City
Montgomery County	Northampton County
Philadelphia County	Northumberland County
	Poquoson City
Rhode Island	Portsmouth City
(Entire state)	Prince William County
Bristol County	Richmond City
Kent County	Richmond County
Newport County	Stafford County
Providence County	Suffolk City
Washington County	Surry County
	Virginia Beach City
South Carolina	Westmoreland County
Beaufort County	Williamsburg City
Berkeley County	York County
Charleston County	
Colleton County	
Georgetown County	
Horry County	
Jasper County	
Virginia	
Accomack County	
Alexandria City	
Arlington County	
Charles City County	
Chesapeake City	
Clifton Forge City	
Essex County	
Fairfax City	
Fairfax County	
Falls Church City	
Gloucester County	
Hampton City	